# A PLUG FOR CLOSING A LACRIMAL CANALICULUS

The present invention relates to a plug for closing the meatus of a lacrimal canaliculus to remedy in particular disorders known as "dry eye" which are due to insufficient secretion of lacrimal liquid.

Numerous plugs are known for performing this function. Most of them are of a shape that is designed to prevent the plug from being expelled or from disappearing into the lacrimal canaliculus. For this purpose, practically all plugs have a top collar which is preferably inclined relative to the general axis of the plug in order to bear against the edges of the meatus and thus constitute means for preventing the plug disappearing into the canaliculus, and also an enlarged portion remote from the collar forming anti-expulsion means.

The drawbacks of known plugs lie in the fact that their shapes do not comply with the natural anatomic shapes of lacrimal canaliculi and constitute sources of trauma to tissues adjacent to such canaliculi.

The present invention seeks to remedy those drawbacks by means of a plug that can be put into place with as little trauma as possible for the tissues concerned, and also that it gives rise to as little as trauma as possible during long-term presence in the canaliculus that it is closing, while nevertheless ensuring that it is held effectively in the canaliculus.

To this end, the invention provides a plug for the meatus of a lacrimal canaliculus, the plug comprising an elongate body having a longitudinal axis and provided at one of its ends with a collar substantially perpendicular to said longitudinal axis, in which the elongate body possesses, adjacent to the collar, a first portion of cross-section that is elliptical with a major axis, and a second portion that extends the first portion obliquely relative to its longitudinal axis in the plane of the

above-mentioned major axis of the section of the first portion.

The general shape of the plug is then closer to the anatomic shape of the lacrimal canaliculus with which it is to co-operate.

In a first embodiment, the second portion of the elongate body comprises two diverging branches, each of cross-section substantially equal to half the cross-section of the first portion.

This shape is well adapted to the morphology of the vertical initial portion of the lacrimal canaliculus to be closed which includes a kind of pocket that is relatively flat parallel to the skin of the subject.

In a second embodiment, the second portion of the elongate body is similar in section to the first portion and is connected to the first portion by a pseudo-hinge formed by a transition zone of cross-section that is narrow in the direction of the major axes of the above-mentioned ellipses. The length of the second portion is long so as to be received in the horizontal portion of the lacrimal canaliculus situated beyond the pocket in order to form a probe for treating the lacrimal canaliculus in which it is placed.

Preferably, in each of the above embodiments, the angle of the second portion relative to the first is maintained elastically, thus enabling the body to be straightened out when the plug is put into place in order to facilitate insertion thereof.

This elasticity is due to the material used, which is elastically deformable away from the shape that is imparted to it during manufacture (for example a biocompatible elastomer or a silicone).

Other characteristics and advantages of the invention appear from the following description of embodiments given below as examples.

Reference is made to the accompanying drawings, in which:

· Figure 1 is a view of the outside of a plug of the invention in a first variant embodiment;

· Figure 2 is a side view of the outside of the plug;

· Figure 3 is a plan view of the plug;

· Figure 4 is a front view of a second variant embodiment of the plug of the invention;

· Figure 5 is a side view of this variant;

· Figure 6 is a section view on line VI-VI of Figure 4;

· Figure 7 is a section view on line VII-VII of Figure 4;

· Figure 8 is a view of the outside of the Figure 4 plug in its angled state; and

· Figures 9 and 10 show two variant embodiments of the plug of the invention put into place in the outlet of a lacrimal canaliculus.

In Figures 1 to 3, the plug shown comprises a top collar 1 of elliptical shape having a segment 2 of an elongate body extending beneath it along a longitudinal axis 2a, the body being likewise elliptical in section with the major axis of the ellipse of the section coinciding with that of the collar 1, said segment 2 forming a first portion of the plug having connected thereto two branches 3 and 4 that diverge away from each other in a plane containing the major axes of the above-mentioned ellipses. The section of each branch 3, 4 is semi-elliptical with the major axis thereof likewise lying in said plane. It should be observed that the center 1a of the elliptical collar 1 does not coincide with the axis 2a, but is offset from said axis 2a along the major axis.

Figure 9 shows this plug in place in the first section of a lacrimal canaliculus 10 which forms a sac 10a flaring from the meatus 10b through which the plug is inserted. In order to insert the plug, it is necessary to move its branches 3 and 4 towards each other by means

of a suitable injector appliance (not shown) so that they occupy space that is no greater than or only slightly greater than the through orifice defined by the meatus 10b of the lacrimal canaliculus 10. On being moved towards each other, the branches 3 and 4 pivot relative to the segment 2 in transition zones 5 and 6 that form pseudo-hinges between the branches and the segments. Like the entire plug, these pseudo-hinges are elastic and tend to cause the branches 3 and 4 to diverge. With a plug made of suitable material, in particular a hydrophilic plastics material of known type, it is possible to prepare the plug by folding down the branches 3 and 4 about their hinges 4 and 5 so that they come into contact with each other, and then by dehydration causing the plug to retain this shape without it being necessary to apply any external stress. It is thus while it is in a shape that is substantially straight that the plug is inserted into the meatus 10b of the lacrimal canaliculus 10. Under the effect of the moisture that is to be found inside the canaliculus, the branches 3 and 4 then diverge progressively so as to reach the state shown in Figure 9.

It should be observed that the sum of the sections of the branches 3 and 4 is substantially equal to the section of the segment 2. The oblong shapes of these segments match the naturally oblong shape of the meatus 10b.

The plug shown in Figures 4 to 8 and in Figure 10 where it is shown implanted in the lacrimal canaliculus 10, is designed to act mainly as a probe for treating disorders of lacrimal canaliculi. Like the above-described plug, it comprises an elliptical top collar 11, a first elongate body portion 12 of elliptical section like the outline of the collar 11 and with a major axis oriented in the same direction, a second elongate body portion 13 identical to the portion 12 in section (which section is shown in Figure 7), and a transition zone 14 which interconnects the first and second portions 12 and

13. The zone 14 is formed by a flattened portion of the plug body of section as shown at 15, such that the major axis of this section is perpendicular to the major axes of the elliptical sections 12 and 13, thereby constituting a preferred bending zone or pseudo-hinge between the portions 12 and 13 of the plug. The flattening defines the plane in which the plug can deform: this plane is the plane containing the major axes of the elliptical sections of the portions 12 and 13 and of the collar 11.

In Figures 4 and 5, the plug is shown straightened out, i.e. under the influence of external forces which may be constituted by the force of gravity if the zone 15 is very flexible, or by a dehydrated state of a hydrophilic material having shape memory in the rest state, i.e. under moist conditions that enable it to be hydrated as shown in Figure 8.

It can be seen that the section of the plug all along its portions 12, 13, and 14 is substantially constant and matches the natural orifice defined by the meatus 10b of the lacrimal canaliculus 10. It will also be observed that when the portions 12 and 13 are in alignment, the section 14 constitutes a highly flexible zone enabling the plug to be inserted into the horizontal portion 10c of the lacrimal canaliculus 10 (see Figure 10).

In a variant embodiment, when at rest, the plug may take up the shape shown in Figure 8, and it needs to be straightened out elastically in order to be inserted into the lacrimal canaliculus. Once therein, it takes up the shape shown in Figure 10.

It will have been observed that the second portion of the plug shown in Figures 4 to 8 is much longer than the second portion of the plug shown in Figures 1 to 3, i.e. the branches 3 and 4. Figures 9 and 10 show the different ways in which they are implanted, and thus the

reason why the portion 13 of the second plug needs to be much longer than the branches 3 and 4 of the first plug.